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IS 10776-1 (1984): Methods of measurement of electroacoustical characteristics of hearing aids, Part 1: General measurements for air-conduction hearing aids [LITD 7: Audio, Video and Multimedia Systems and Equipment]



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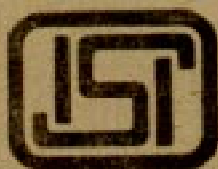
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Indian Standard

**METHODS OF MEASUREMENT OF THE
ELECTRO-ACOUSTICAL CHARACTERISTICS
OF HEARING AIDS**

**PART 1 GENERAL MEASUREMENTS FOR
AIR-CONDUCTION HEARING AIDS**

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MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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Indian Standard
**METHODS OF MEASUREMENT OF THE
ELECTRO-ACOUSTICAL CHARACTERISTICS
OF HEARING AIDS**

**PART 1 GENERAL MEASUREMENTS FOR
AIR-CONDUCTION HEARING AIDS**

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Emeritus Scientist
National Physical Laboratory (CSIR)
New Delhi

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Indian Standard

METHODS OF MEASUREMENT OF THE ELECTRO-ACOUSTICAL CHARACTERISTICS OF HEARING AIDS

PART 1 GENERAL MEASUREMENTS FOR AIR-CONDUCTION HEARING AIDS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 27 January 1984, after the draft finalized by the Acoustics Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 The determination of the electro-acoustic characteristics of a hearing aid requires test methods that are clearly defined and reproducible to provide information that can be reasonably related to the use of such devices and to facilitate the exchange of information on hearing aid performance.

0.3 This standard is designed to be a basic document specifying a wide range of measurement methods from which those applicable to particular needs can be selected. It is not necessarily intended that all measurements described herein should be made in every case. The test methods described include numerous hearing aid performance parameters that are felt to be significant in predicting the suitability of a hearing aid for various applications.

0.4 The purpose of this standard is to describe measuring methods for the evaluation of the electro-acoustical characteristics of hearing aids. The methods are chosen first of all to be practical and reproducible, and consequently they are based on some fixed parameters chosen arbitrarily to a certain extent. This should be taken into consideration when comparisons are being made between test results for hearing aids of different models and manufacture, and in each case it is advisable to examine to what extent the arbitrarily chosen parameters will influence the comparison of such test results.

0.5 The test results obtained by methods specified in this standard express the performance under the conditions of the test and may

deviate substantially from the performance of the hearing aid under practical conditions of use.

0.6 It is not the intent of this standard to restrict the variety of hearing aid performance and characteristics available, nor to inhibit in any way advances in the state of the art.

0.7 The methods of measurements for the characteristics of hearing aids were earlier covered by IS : 3641-1976*. This standard is now superseded by the series of standards listed in **0.8.1**. These methods have been revised keeping in view the revision of the corresponding IEC Publication.

0.8 A series of Indian Standards is therefore, being brought out covering characteristics which are useful for their specifications and the methods of measurements of the electro-acoustical characteristics of hearing aids.

0.8.1 These methods of measurement are being covered in a series of standards consisting of the following parts :

- Part 1 General measurements for air conduction hearing aids
- Part 2 Additional measurements for hearing aids with induction pick-up coil input
- Part 3 Additional measurements for hearing aids with automatic gain control circuits
- Part 4 Measurement of characteristics of hearing aids with bone vibrator outputs

0.9 While preparing this standard, assistance has been derived from IEC Pub 118-0 (1983) 'Hearing aids : Part 0 Measurement of electro-acoustical characteristics' issued by the International Electrotechnical Commission.

0.10 In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960†.

1. SCOPE

1.1 This standard (Part 1) specifies the methods of measurement of physical performance characteristics of air-conduction hearing aids based on a free field technique.

*Method of measurements on hearing aids (*first revision*).

†Rules for rounding off numerical values (*revised*).

2. TERMINOLOGY

2.0 For the purpose of this standard, the following terms and definitions in addition to those given in IS : 1885 (Part 3/Sec 5)-1966* shall apply.

2.1 Acoustic Coupler — A coupler is a cavity of predetermined shape and volume, which is used for the electro-acoustic measurements of earphones in conjunction with a calibrated microphone adopted to measure the pressure developed within the cavity.

2.2 Substitution Method — A method of measurement in which the hearing aid and the microphone employed to measure the free field sound pressure, are placed alternately at the same point in the sound field.

2.3 Comparison Method — A method of measurement in which the hearing aid and the microphone employed to measure the free-field sound pressure are placed simultaneously at two different points symmetrical with respect to the axis in the sound field.

2.4 Pressure Method — A method of measurement in which the input sound pressure level is controlled close to the sound entrance opening of the hearing aid by a pressure calibrated controlling microphone, thus substantially eliminating diffraction effects from the hearing aid.

2.5 Simulated *in-situ* Method — A method of measurement in which the hearing aid is mounted upon an artificial head and torso in order to simulate the acoustical effects of an average adult wearer.

2.6 Reference Orientation (of a Hearing Aid) — The orientation of a hearing aid in the test enclosure with respect to the sound source, which corresponds to the orientation of a hearing aid under actual use on a person facing the sound source.

2.7 Reference Point (of a Hearing Aid) — A point on the hearing aid chosen for the purpose of defining its position, normally the centre of the main sound entry to the aid.

2.8 Test Point — A position in the test enclosure to which the measurements of the free-field sound pressure level are referred and at which the reference point of the hearing aid is located for test purposes.

2.9 Supply Voltage — The voltage at the battery terminals of the hearing aid with the hearing aid switched on.

2.10 Acoustic Gain — At a specified frequency and under specified operating conditions. The difference between the sound pressure level

*Electrotechnical vocabulary : Part 3 Acoustics, Section 5 Speech and hearing.

developed in the acoustic coupler by the hearing aid and the sound pressure level measured at the test point.

2.11 Full-on Acoustic Gain — At a specified frequency and under essentially linear input-output conditions, the acoustic gain obtainable from the hearing aid measured with the gain control at maximum (full-on) and at stated settings of the other hearing aid controls.

2.12 Maximum Acoustic Gain at a Specified Frequency — The highest possible acoustic gain that can be obtained from the hearing aid at the specified frequency.

2.13 High-Frequency Average (HFA) Full-on Gain — The average of the 1 000, 1 600, and 2 500 Hz values of full-on gain.

2.14 Saturation Sound Pressure Level — The highest possible sound pressure level obtainable in the acoustic coupler from the hearing aid at a specified frequency.

NOTE — The saturation sound pressure level does not necessarily occur at the highest input level.

2.15 Saturation Sound Pressure Level Curve — Saturation sound pressure level expressed as a function of frequency.

2.16 Maximum Saturation Sound Pressure Level — The highest point of a saturation sound pressure level curve.

2.17 Output Sound Pressure Level for an Input Sound Pressure Level of 90 dB (OSPL₉₀) at a Specified Frequency — The sound pressure level produced in the acoustic coupler with an input sound pressure level of 90 dB at the specified frequency and the gain control in the full-on position. The abbreviation for this term is OSPL₉₀.

2.18 OSPL₉₀ Curve — OSPL₉₀ expressed as a function of frequency.

2.19 High-Frequency Average (HFA) OSPL₉₀ — The average of the 1 000, 1 600, and 2 500 Hz values of OSPL₉₀.

2.20 Reference Test Frequency — The frequency, at which the setting of the gain control is made in relation to OSPL₉₀ to obtain a reference test position of the gain control. The reference test frequency shall be 1 600 Hz.

2.21 Reference Test Gain Control Position — The setting of the hearing aid gain control which provides an output sound pressure level in the coupler of 15 ± 1 dB less than OSPL₉₀ for an input sound pressure level of 60 dB at the reference test frequency. If the gain available will not permit this, the full-on gain control position of the hearing aid should be used.

2.22 Reference Test Gain — The acoustic gain of the hearing aid at the reference test frequency with the setting of the gain control to the reference test gain control position.

2.23 Frequency Response — The sound pressure level developed in the acoustic coupler by the hearing aid expressed as a function of frequency under specified test conditions for constant input free-field sound pressure level.

2.24 Comprehensive Frequency Response Curves — A family of frequency response curves obtained with the gain control in the reference test gain position using a series of input sound pressure levels to exhibit the input-output characteristics of the hearing aid over its full range of operation.

2.25 Basic Frequency Response Curve — The frequency response curve obtained at the reference test gain setting with an input sound pressure level of 60 dB.

2.26 Steady State Input-Output Graph — The graph illustrating the output sound pressure level as a function of the input sound pressure level at a stated frequency and gain control setting, both expressed in dB on identical linear scales.

3. GENERAL REQUIREMENTS FOR MEASUREMENTS

3.0 The acoustic test procedure specified in this standard is based on the free-field technique in which the hearing aid is placed in a plane progressive wave, with the earphone coupled to a standardized coupler, and the sound pressure generated by the hearing aid in the cavity of the coupler being measured by a condenser microphone. The measurements specified are based on the substitution method in which the reference point of the hearing aid is made to coincide with the test point chosen on the axis of the sound source.

3.1 Atmospheric Conditions for Measurements — Unless otherwise specified, all the measurements shall be made within the following atmospheric conditions :

Temperature	15 to 35° C
Relative humidity	less than 80 percent
Air pressure	86 to 106 kPa (1 bar = 10^5 Pa)

NOTE — The temperature at which measurements are carried out shall be recorded.

3.2 Frequencies of Measurements

3.2.1 Reference Test Frequency — Unless otherwise specified, the reference test frequency for measurements shall be 1 600 Hz.

3.2.2 Frequency Range — The frequencies for measurements shall cover a range of at least 200 to 8 000 Hz.

3.2.3 Test Frequencies — For measurements made at a number of frequencies, the frequencies shall be selected from Table 1 of IS : 2264-1963*.

3.3 Reference Sound Pressure — The reference sound pressure level with respect to which all sound pressure levels are specified is 20 μ Pa.

3.4 Magnetic Field Strength — The magnetic field strength is expressed in A/m or mA/m.

3.5 Test Environment — Measurements shall be made under the free-field conditions in anechoic chambers or outdoors or under simulated free-field conditions. Free-field conditions may be assumed over the region of space over which the sound pressure variations from the inverse law do not exceed ± 1 dB. The conditions specified in 3.5.1 and 3.5.2 should be ensured during the measurements.

3.5.1 Measurements shall be made with the sound source and the microphone in a location which is free from disturbing elements in the form of standing waves, wind, stray magnetic and electric fields, and acoustical noise.

3.5.1.1 The total disturbing voltage due to wind, stray magnetic and electric fields, and acoustic noise shall be at least 10 dB below the output resulting from the applied signal.

3.5.1.2 The pressure at the microphone position, due to reflections from the surrounding objects, shall be at least 10 dB below the pressure of the sound waves arriving directly from the source.

3.5.2 It is also necessary to ensure that the sound pressure produced in the coupler by the earphone is at least 10 dB above sound pressure which the sound source energizing the hearing aid may produce directly in the coupler.

3.6 Unless otherwise specified, all measurements shall be carried out without using an ear insert or ear mould which is normally to be regarded as incorporated in the coupler employed.

3.7 Accuracy of Measurements — The accuracy of all measurements shall be stated in the test report.

*Preferred frequencies for acoustical measurements.

3.8 Graphical Representation of Hearing Aid Characteristics — A logarithmic scale for frequency, sound pressure, amplification, etc, shall be used (see IS : 8159-1976*).

4. TEST EQUIPMENT

4.1 Acoustical Requirement for the Test Enclosure

4.1.1 The test enclosure shall provide essentially free-field conditions over the frequency range 200 to 8 000 Hz. Essentially free-field conditions are considered established when the sound pressure level at the positions 100 mm in front of and behind the test point do not deviate from the inverse distance law $\left(\frac{1}{r} \text{ law} \right)$ more than ± 2 dB from 200 to 400 Hz and ± 1 dB from 400 to 8 000 Hz. At the positions 100 mm, right, left, above and below the test point, the SPL shall not deviate more than ± 1 dB from the SPL in the test point in the frequency range 200 to 8 000 Hz. The hearing aid and any other obstacles shall not be present in the test enclosure during the testing of the sound field.

NOTE — As the testing of hearing aids is often undertaken in small test enclosures it is essential that the characteristics of these small enclosures are known and that they compare or simulate favourably with the larger chamber meeting the above requirement. If the above requirement is unlikely to be met a comparison should be made between an anechoic chamber and a smaller enclosure.

4.1.2 The sound pressure level of the ambient noise in the free-field test enclosure in the frequency range 200 to 8 000 Hz shall be sufficiently low to ensure that the reading shall drop at least 10 dB when the test signal is switched off.

4.2 Sound Field at the Test Point — The sound source shall be capable of producing at the test point requisite sound pressure levels between 50 and 90 dB constant over the frequency range within the following tolerances :

when the substitution method is used : ± 1 dB over the frequency range 200 to 5 000 Hz, and ± 1.5 dB over the frequency range 5 000 to 8 000 Hz;

when the comparison method is used : ± 1.5 dB over the frequency range 200 to 3 000 Hz, and ± 2 dB over the frequency range 3 000 to 8 000 Hz.

The frequency of the sound source shall be within ± 2 percent of the indicated value.

* Specification for scales and sizes for plotting frequency characteristics and polar diagrams.

The total harmonic distortion of the acoustical signal of the sound source shall not exceed 1 percent up to an input SPL of 70 dB and 2 percent for an input SPL greater than 70 dB and up to 90 dB. For distortion measurement the total harmonic distortion of the acoustical signal of the sound source shall not exceed 0.5 percent.

4.3 Acoustic Coupler — For all measurements the reference coupler, in accordance with IS : 10781-1984* shall be used.

4.4 Equipment for the Measurement of Acoustic Coupler Sound Pressure Level — The equipment used for measurement of the coupler sound pressure level produced by the hearing aid, shall comply with the following requirements.

4.4.1 The calibration of the sound pressure level measurement system shall be accurate within ± 0.5 dB at a specified frequency.

NOTE — The calibration of the microphone should be repeated sufficiently often to ensure that it remains within the permitted limits during measurements.

4.4.2 The pressure sensitivity level of the measuring microphone shall be frequency independent within ± 1 dB in the frequency range 200 to 3 000 Hz and within ± 2 dB in the range 3 000 to 8 000 Hz relative to the pressure sensitivity level at 1 000 Hz.

4.4.3 Total harmonic distortion in the measuring equipment shall be less than 1 percent for sound pressure levels up to 130 dB in the frequency range 200 to 5 000 Hz and less than 3 percent for sound pressure levels above 130 dB and up to 145 dB.

4.4.4 The sound pressure level corresponding to hum, thermal agitation and other noise sources shall be sufficiently low to ensure that the reading shall drop at least 10 dB when the test signal is switched off.

For this purpose a high-pass filter not affecting frequencies of 200 Hz and above may be employed.

NOTE — Noise level should be indicated on the response curve.

4.4.5 The output indicator used shall give rms indication within a tolerance of ± 0.5 dB at a signal crest factor of not more than 3.

NOTE 1 — If under certain conditions it is necessary to use a selective measuring system in order to ensure that the response of the hearing aid to the signal can be differentiated from inherent noise in the hearing aid, the use of the selective system should be stated in the report.

NOTE 2 — It is well known that the type of output indicator employed may influence the test results significantly if a non-sinusoidal voltage is being measured. Such non-sinusoidal voltages may be present when making measurements with high input level.

*Specification for reference coupler for the measurement of hearing aids using earphones coupled to the ear by means of ear inserts (*under print*).

4.4.6 Since the calibration of the acoustic coupler depends on ambient conditions especially the atmospheric pressure, corrections for such a dependence shall be made when necessary (*see* 3.1).

4.5 Equipment for Automatic Sweep Frequency Recording — The equipment shall be capable of maintaining at the test point all requisite sound pressure levels between 50 and 90 dB within such tolerances as specified in 4.2.

The indicated frequency on a recorder chart shall be accurate within ± 5 percent. The automatically recorded values shall not differ more than 1 dB from the steady state value over the frequency range 200 to 5 000 Hz and not more than 2 dB above 5 000 Hz up to 8 000 Hz.

4.6 Calibration of Free-Field Sound Pressure Level — The calibration of the free-field sound pressure level shall be accurate within ± 0.5 dB at a specified frequency. The free-field sensitivity level of the measuring microphone shall be frequency-independent within ± 1 dB in the frequency range 200 to 5 000 Hz and within ± 1.5 dB in the range 5 000 to 8 000 Hz relative to the free-field sensitivity level at a specified frequency.

NOTE — For the comparison method it is recommended that a half-inch microphone should be used as control microphone.

5. CONDITIONS OF MEASUREMENTS

5.1 Choice of Test Point — With the position of the sound source fixed in the test enclosure, a test point is chosen, so that the requirements of 4.1 are fulfilled.

The distance from the sound source to the test point shall be sufficient to prevent interaction between the sound source and the hearing aid when the latter is located at the test point. Usually a distance of 0.5 to 1.5 m from the sound source is chosen. When making measurements using the substitution method, the test point is usually on the axis of the sound source. When making measurements using the comparison method, the test point is chosen about 30 to 60 mm off the axis.

NOTE — A distance of 60 to 120 mm from the control microphone to the hearing aid is usually sufficient when both the hearing aid and the control microphone have small physical dimensions.

The choice of the test point shall allow for a reproducible positioning of the test object within ± 10 mm.

5.2 Calibrating the Sound Field — The technique used for the calibration of the sound field differs for the substitution and comparison methods.

5.2.1 Substitution Method — The calibration of the sound field at the test point is made, with the hearing aid absent, note being made of the electrical input to the sound source required to provide the sound pressure levels desired for a particular test.

5.2.2 Comparison Method — The sound pressure at the test point is kept constant using a control microphone and the equipment mentioned in 4.5. The hearing aid is placed at the position specified in 5.3.

5.3 Locating the Hearing Aid for Test

5.3.1 Reference Point and Reference Orientation of the Hearing Aid — The reference point chosen for a particular hearing aid shall normally be the centre of the main microphone opening area.

If another reference point is being used it should be stated in the report.

The hearing aid is placed in the test enclosure in the reference orientation.

A hearing aid for which the reference orientation cannot be accurately defined (see 2.6) shall be placed with the surface in which the reference point is located, facing towards the sound source in such a way that the direction of the incident sound is perpendicular to the surface where the reference point is located.

The reference point of the hearing aid shall coincide with the test point (see 5.1).

5.3.2 Mechanical Support for the Hearing Aid — Care should be taken that neither the coupler nor the mechanical support for the hearing aid will appreciably disturb the sound field in the vicinity of the hearing aid at the test frequencies used, and they should not introduce spurious effects arising from mechanical resonances or mechanical vibrations, nor should they in any respect affect any mechanical or acoustical property of the hearing aid under test.

The hearing aid shall be placed in the free-field without any baffle or other device simulating the body or parts of the body of a wearer.

The ear simulator shall be so placed in relation to the sound field as to produce the least distortion in that field at the sound entry of the hearing aid.

5.4 Normal Operating Conditions for the Hearing Aid — The normal hearing aid conditions to apply for measurements when no other conditions are prescribed are as given in 5.4.1 to 5.4.6.

5.4.1 Location — The hearing aid is located as described in 5.3 according to the method of measurement used.

5.4.2 Battery or Supply Voltage — The type of power source used and the supply voltage shall be stated. The measurements shall be made at the supply voltage stated by the manufacturer within ± 2 percent tolerance.

NOTE — Either a battery of the type normally used in the hearing aid, particularly discharged to avoid typical high initial voltage, or a suitable power supply that simulates the partially discharged voltage and internal impedance of real batteries of the type normally used may be employed.

5.4.3 Gain Control — Full-on gain position and reference test gain position or other used positions shall be stated.

5.4.4 Other Controls — The setting elected for the tone control shall be stated in the report on test results. In general, the basic setting, that is, that giving the widest frequency range, shall be selected in preference to settings in which the low or high frequencies are attenuated. If, however there are reasons for regarding some other setting as more representative of the normal use of the hearing aid, these settings may be adopted provided they are clearly described in the report.

All other control settings should be chosen to give the highest OSPL₉₀ and the highest acoustic gain. If this is not possible, the setting giving the highest OSPL₉₀ should be selected. All control settings selected shall be stated in the report on test results.

5.4.5 Sound Outlet Systems — The particular system, that is, insert earphone, acoustic tubing, etc, to be used shall be stated (see IS : 10781-1984*).

5.4.6 Accessories Used in Connection with the Hearing Aid Microphone Opening — The particular accessories to be used shall be stated.

6. MEASUREMENTS

6.0 Data should be quoted for that part of the frequency range between 200 and 8 000 Hz over which the output of the hearing aid falls by at least 10 dB when the signal source is switched off.

6.1 Saturation Sound Pressure Level (see 2.14) — The purpose of this test is to determine the highest possible sound pressure level that the

*Specification for the reference coupler for the measurement of hearing aids using earphones coupled to the ear by means of ear inserts (*under print*).

hearing aid is capable of producing in the coupler allowing all possible settings of the hearing aid controls and the values of input sound pressure level and frequency.

6.1.1 Test Procedure

6.1.1.1 Turn the gain control full-on and set other controls into desired positions.

6.1.1.2 At a given frequency increase the input SPL until the maximum value of the coupler SPL is obtained, and record the SPL.

6.1.1.3 Repeat the procedure at a sufficient number of frequencies within the frequency range 200 to 8 000 Hz.

6.1.1.4 Plot the coupler SPL against frequency. From this curve determine the maximum saturation sound pressure level.

This test procedure is particularly adapted to point-by-point measurement. If automatic recording methods with constant high input SPL is used it is important to secure that the test results obtained over the frequency range of interest correspond with the results obtained using the point-by-point measurement.

NOTE — The output signal at saturation will contain high levels of distortion products, therefore, the methods of measurement may influence the level measured. If the output signal is measured through a filter centred at the frequency of the test signal, this may result in lower levels than may be achieved using a wide band instrument. It is therefore, recommended that wide band measurements only should be made for the purpose of this measurements described in this standard.

6.2 Sound Pressure Level Curve for an Input SPL of 90 dB (OSPL₉₀ Curve) (see 2.17) — The purpose of this test is to determine the frequency response of the sound pressure level obtained in the coupler when using an input SPL of 90 dB and the gain control in a full-on position.

6.2.1 Test Procedure

6.2.1.1 Turn the gain control full-on and set other controls into desired positions.

6.2.1.2 At a given frequency increase the input SPL until the maximum value of the coupler SPL is obtained, and record the SPL.

6.2.1.3 Adjust the input SPL to 90 dB at a suitable frequency.

6.2.1.4 Vary the frequency of the sound source over the recommended frequency range from 200 to 8 000 Hz keeping the input SPL constant at 90 dB and record the SPL in the coupler.

6.3 Full-on Acoustic Gain Frequency Response (*see 2.11 and 2.12*) — The purpose of this test is to determine the full-on acoustic gain obtainable with the hearing aid. The output SPL in the coupler is measured at full-on gain control setting with an input SPL sufficiently low to ensure essentially linear input-output conditions.

6.3.1 Test Procedure

6.3.1.1 Turn the gain control full-on and set other controls into desired positions.

6.3.1.2 At a suitable frequency adjust the input SPL to 60 dB or, if this does not produce essentially linear input-output conditions to 50 dB SPL. Essentially linear input-output conditions are considered to exist if at all frequencies within the range 200 to 8 000 Hz a change of the input SPL of 10 dB causes a change of the recorded output level of 10 ± 1 dB. The input SPL shall be stated.

NOTE — For hearing aids with certain circuit arrangements, for example, push-pull aids, non-linear input-output characteristics may be observed over a large portion of the operating range.

6.3.1.3 The frequency response with full-on gain is measured by varying the frequency of the sound source over the recommended frequency range 200 to 8 000 Hz keeping the input SPL constant.

6.3.1.4 The full-on acoustic gain is plotted *versus* frequency and may be reported for a specified frequency.

6.3.1.5 HF-average full-on gain — The HF-average full-on gain is the average of the 1 000, 1 600, and 2 500 Hz full-on gain values.

6.4 Comprehensive Frequency Response and Basic Frequency Response (*see 2.23 and 2.25*) — The purpose of this test is to show the effect of input sound pressure level on the frequency response of the hearing aid. The resulting family of curves will depict the comprehensive frequency responses and will indicate the input-output characteristics of the hearing aid.

6.4.1 Test Procedure

6.4.1.1 Adjust the gain control to the reference test gain position (*See 2.22*) and set other controls into desired positions.

6.4.1.2 Vary the frequency of the sound source over the recommended frequency range 200 to 8 000 Hz keeping the input SPL constant at 50, 60, 70, 80 dB and 90 dB or with such other input sound pressure levels as will adequately show the behaviour of the hearing aid at various input levels.

6.4.1.3 The frequency response is plotted as the coupler SPL *versus* frequency at constant input SPL, with a curve for each of the input sound pressure levels used. The curves will thus be parallel curves with a distance of 10 dB between neighbouring curves in the range where essentially linear input-output relations apply.

6.4.1.4 The basic frequency response (*see 2.25*) is the curve at an input level of 60 dB.

NOTE — The basic frequency response curve for hearing aids with directional microphones may be measured in a number of stated orientations relative to the reference orientation.

6.4.2 Frequency Range — The test procedure is:

- a) from the manufacturers specified frequency response curve, determine the average of the 1 000, 1 600, and 2 500 Hz response levels;
- b) subtract 20 dB;
- c) draw a horizontal line parallel to the frequency axis at the reduced level;
- d) note the lowest frequency f_1 at which the response curve intersects the horizontal line; and
- e) note the highest frequency f_2 at which the response curve intersects the horizontal line. and

6.4.2.1 The frequency range of the hearing aid shall be considered as being between f_1 and f_2 .

6.5 Effect of Tone Control Position on the Basic Frequency Response—
The purpose of this test is to show the effect of tone control position on the basic frequency response of the hearing aid.

6.5.1 Test Procedure

6.5.1.1 Adjust the tone control in the hearing aid according to **5.4.4**.

6.5.1.2 Adjust the gain control to the reference test gain position (*see 2.22*) and set other controls into desired positions.

6.5.1.3 Vary the frequency of the sound source over the recommended frequency range 200 to 8 000 Hz, keeping the input SPL constant at 60 dB.

6.5.1.4 Repeat the test with the tone control settings available.

6.5.1.5 The frequency response at the various tone control settings should be plotted together with the basic frequency response as the coupler SPL *versus* frequency.

6.6 Effect of Gain Control Position on Frequency Response — The purpose of this test is to show the effect, if any, of gain control positions on the frequency response of the hearing aid.

6.6.1 Test Procedure

6.6.1.1 Proceed as mentioned under 6.3.1.1, 6.3.1.2 and 6.3.1.3.

6.6.1.2 Adjust the gain control from a full-on position downward in approximately 10 dB steps at the reference frequency.

6.6.1.3 At each setting of the gain control vary the frequency over the recommended range from 200 to 8 000 Hz keeping the input SPL constant.

6.6.1.4 The frequency responses at each gain control position should be plotted as the coupler SPL *versus* frequency.

6.7 Characteristics of the Gain Control — The purpose of this test is to determine the characteristic of the gain control, expressed as acoustic gain relative to full-on acoustic gain *versus* mechanical settings of the control.

6.7.1 Test Procedure

6.7.1.1 Turn the gain control full-on.

6.7.1.2 Adjust the input SPL to a sufficiently low value at the reference frequency (*see* 6.3.1.2).

6.7.1.3 Determine the acoustic gain.

6.7.1.4 Repeat the tests with a sufficient number of other settings of the gain control to cover the range of the control.

6.7.1.5 The acoustic gain is plotted relative to the full-on acoustic gain *versus* settings of the gain control, using a linear scale for the positions of the control.

6.8 Effect on the Full-on Acoustic Gain of Variation of Battery or Supply Voltage — The purpose of this test is to determine the effect on the full-on acoustic gain of variation of battery or supply voltage.

6.8.1 Test Procedure

6.8.1.1 Proceed as mentioned under 6.7.1, 6.7.2 and 6.7.3.

6.8.1.2 Repeat the test for various values of the supply voltage within the specified voltage range for normal operation of the battery.

6.8.1.3 Plot the full-on acoustic gain relative to the full-on gain obtained at normal battery voltage, *versus* voltage.

6.9 Effect on the Full-on Acoustic Gain of Variation of Internal Resistance of Battery or Supply — The purpose of this test is to determine the effect on the full-on acoustic gain of variation of internal resistance of battery within the resistance range of interest for the battery types recommended for the hearing aid.

6.9.1 Test Procedure

6.9.1.1 Proceed as mentioned under 6.7.1, 6.7.2 and 6.7.3.

6.9.1.2 Repeat the test at a constant supply voltage for various values of the internal resistance.

6.9.1.3 Plot the acoustic gain relative to the gain obtained at normal internal resistance *versus* internal resistance.

6.10 Effect on OSPL₉₀ of Variation of Battery or Supply Voltage — The purpose of this test is to determine the effect on OSPL₉₀ of variation of battery or supply voltage.

6.10.1 Test Procedure

6.10.1.1 Turn the gain control full-on.

6.10.1.2 Adjust the frequency to the reference frequency (*see* 2.20).

6.10.1.3 Adjust the input SPL to 90 dB.

6.10.1.4 Measure the OSPL₉₀.

6.10.1.5 Repeat the test for various values of the supply voltage within the voltage range for the hearing aid.

6.10.1.6 Plot the OSPL₉₀ values relative to the value obtained at normal battery voltage *versus* voltage.

6.11 Battery Current — The purpose of this test is to determine the battery current.

6.11.1 Test Procedure

6.11.1.1 With the gain control in the reference test gain position measure the battery current at the reference test frequency and at an input SPL of 60 dB.

6.11.1.2 The direct-current measuring system shall have the following characteristics:

- a) An accuracy of ± 5 percent at the value of current measure;
- b) A direct current resistance not exceeding $50/I$, when I is the current being measured, in milliamperes; and
- c) An alternating current impedance not exceeding 1 ohm over the frequency range 200 to 8 000 Hz.

NOTE — One method of realizing (c) is to bypass the current meter with an 8 000 μF capacitor. The capacitor should not shunt the battery or power supply.

6.12 Measurement of Amplitude Non-linearities in Hearing Aids — The purpose of this test is to determine the degree of the amplitude non-linearity in the sound output under specified conditions.

The amplitude non-linearity can be described by the degree of :

- a) *Harmonic Distortion* — Distortion products generated by the action of a non-linear transfer function at integer multiples of the test signal frequency.

The harmonic distortion products appear at frequencies above the input signal frequency. This means that for hearing aids at higher frequencies they may fall outside the frequency range of the earphone as measured in a coupler.

For the lower frequency range, the harmonic distortion products give a suitable description of the non-linearity.

- b) *Intermodulation Distortion* — Distortion products generated by the action of a non-linear transfer function on an input signal composed of at least two signals of different frequencies.

Intermodulation distortion products, for instance those measured by the difference-frequency distortion method, are more sensitive to non-linearity in the higher frequency range than are harmonic distortion products.

6.12.1 Harmonic Distortion

6.12.1.1 Harmonic distortion is measured using an input signal of one sinusoidal tone having the frequency f . The distortion products have the frequency nf , n being an integer. Total harmonic distortion, or harmonic distortion of the n th order, is defined as the ratio of the

output sound pressure of the total harmonic distortion products, or at the frequency nf respectively, to the total output sound pressure and can be expressed as a percentage or in decibels.

The total harmonic distortion is given by the formula

$$\sqrt{\frac{P_2^2 + P_3^2 + P_4^2 + \dots}{P_1^2 + P_2^2 + P_3^2 + P_4^2 + \dots}}$$

and harmonic distortion of the n th order by the formula

$$\sqrt{\frac{P_n^2}{P_1^2 + P_2^2 + P_3^2 + P_4^2 + \dots}}$$

where, P_1 is the sound pressure of the fundamental frequency of the signal in the coupler and $P_2, P_3, P_4, \dots, P_n$ are the sound pressures of the harmonic components of the second, third, fourth, n th order.

6.12.1.2 Test Procedure

- a) Adjust the gain control of the hearing aid to the reference test gain position. The position of other controls shall be stated in the report, preferably these should be set to a position that gives the widest bandwidth.

NOTE — The reference test gain position is defined as the setting of the hearing aid gain control so that the output sound pressure level in the acoustic coupler, at the reference test frequency with a pure-tone input sound pressure level of 60 dB, is 15 dB less than the output sound pressure level at the test frequency for a 90 dB input sound pressure level with the gain control of the hearing aid full-on. If the gain available will not permit this, the full-on gain control position of the hearing aid should be used. The reference test frequency is 1 600 Hz but for certain hearing aids a higher frequency may be appropriate, for example, 2 500 Hz. In this case, the reference frequency should be stated.

- b) Vary the frequency of the sound source over the frequency range 200 Hz to 8 000 Hz with an input sound pressure level of 70 dB and analyze the output signal for levels at the harmonic frequencies nf or record the total harmonic distortion content. The bandwidth of the filter should be stated. For continuous recording, the sweep rate shall be such that the response does not differ more than 1 dB from the steady-state value at any frequency.

In the event that the response curve rises 12 dB more between any test frequency and its second harmonic, distortion tests at that frequency may be omitted.

NOTE 1 — In case spot frequencies are used for measurement, the frequencies used shall be among the preferred frequencies.

NOTE 2 — A total harmonic distortion meter, whose function is described by the first equation of 6.12.1, measures the residue after the fundamental component is removed. Thus noise, such as ambient noise in the test space or self-noise in the hearing aid, will appear as a distortion product. The reading of distortion on the distortion meter should decrease by at least 10 dB when the input signal is turned off. Otherwise, the accuracy of the measurement will be degraded.

- c) If required, repeat the procedure described in item (b) with other input sound pressure levels.
- d) Plot the harmonic distortion against the frequency of the sound source *versus* the input sound pressure level.

6.12.2 Intermodulation Distortion — Difference-Frequency Distortion — Difference-frequency distortion is measured using an input signal composed of two sinusoidal signals f_1 and f_2 , having amplitudes within 1.5 dB, f_2 being higher in frequency than f_1 . The levels of the second order $f_2 - f_1$, and the third order $2f_1 - f_2$, distortion products shall be measured and expressed as a percentage or in decibels referred to the output level of f_2 . Higher order components may also be measured.

6.12.2.1 Test procedure

- a) Adjust the gain control of the hearing aid to the reference test gain position. The position of other controls shall be stated in the report.
- b) Adjust the frequencies of the test signals f_1 and f_2 such that $f_2 - f_1 = 250$ Hz.

NOTE — Frequency differences other than 250 Hz may be appropriate and when used the frequency difference should be stated, for example, if the signal-to-noise ratio is too low at 250 Hz, a higher frequency difference may be used.

- c) Select a suitable number of frequencies f_1 and f_2 of the sound source or sources within the frequency range 350 to 5 000 Hz, maintaining the selected difference frequency and keeping the sound pressure level of each of the two test tones at 64 dB. Measure the sound pressure levels at the frequencies $f_2 - f_1$ and $2f_1 - f_2$ with a suitable filter. The output level at the filter terminals should decrease by at least 10 dB when the test signal f_2 is switched off. The bandwidth of the filter should be stated.
- d) If additional information with respect to input level is deemed to be significant, repeat the procedure described in (c) at other appropriate input levels.
- e) Plot the difference-frequency distortion products as two curves or tabulate them for each input level, one for the

second order, and one for the third order products as a function of the higher frequency (f_2).

NOTE — Although the upper limit of the frequency range is restricted to 5 000 Hz, it is recognized that a considerable amount of intermodulation distortion may occur at higher input frequencies.

6.13 Effect on Amplitude Non-linearities of Variation of Battery or Supply Voltage and Internal Impedance

6.13.1 The purpose of this test is to determine the effect on the amplitude non-linearity of variation of battery or supply voltage and of variation of internal impedance of the battery or the power supply.

6.13.2 Repeat the procedure described in 6.12, using appropriate battery or supply voltages within the range stated by the hearing aid manufacturer.

6.14 Internal Noise Generated in the Hearing Aid — The internally generated noise in the hearing aid can be measured in a simple manner as described in 6.14.1, or alternatively analyzed in third-octave bands, as described in 6.14.2. The method used shall be reported with the results.

6.14.1 Simplified Method—With this method, the internally-generated noise is expressed as an equivalent input noise level. The ambient noise in the test space shall be negligible.

NOTE — Without measuring the spectrum of the ambient noise in the test space, as in the third-octave band method, it is difficult to assess its contribution to the total noise level measured in the coupler. Therefore, care should be taken to ensure that this ambient noise does not influence the test results.

6.14.1.1 Test procedure

- a) Adjust the gain control of the hearing aid approximately to the reference test gain position. For the purpose of this test a precise position of the gain control is not required. The position of other controls shall be stated in the report.

NOTE — The reference test gain position is defined as the setting of the hearing aid gain control so that the output sound pressure level in the acoustic coupler, at the reference test frequency with a pure-tone input sound pressure level of 60 dB, is 15 dB less than the output sound pressure level at the test frequency for a 90 dB input sound pressure level with the gain control of the hearing aid full-on. If the gain available will not permit this, the full-on gain control position of the hearing aid should be used.

The reference test frequency is 1 600 Hz, but for certain hearing aids a higher frequency may be appropriate, for example, 2 500 Hz. In this case, the reference frequency should be stated.

- b) Measure the output sound pressure level L_o in the acoustic coupler at the reference test frequency with a pure-tone input sound pressure level L_1 of 60 dB.

NOTE — For automatic gain control (AGC) hearing aids, an input sound pressure level of 60 dB may be too high and should be reduced to a lower level which ensures essentially linear input-output conditions. In this case, the input sound pressure level should be stated.

- c) Switch off the sound source and measure the sound pressure level L_n in the coupler caused by the internally generated noise. To determine that the noise in the coupler and the coupler microphone system is adequately low, the measured noise should decrease by at least 10 dB when the hearing aid is turned off.

- d) Calculate the equivalent input noise level L_N as follows:

$$L_N = L_2 - (L_s - L_1)$$

where

L_2 = the sound pressure level in the coupler as measured in (c);

L_s = the sound pressure level in the coupler at the reference test frequency as measured in (b);

L_1 = the input sound pressure level at the reference test frequency (60 dB).

6.14.2 Third-Octave Band Analysis Method (see Fig. 1) — With this method the internally generated noise as a function of frequency is expressed in terms of the equivalent input sound pressure level in third-octave bands (see IS : 6964-1973*).

6.14.2.1 Test procedure

- a) With the sound source switched off, the sound pressure level of the ambient noise in the test space shall be measured in third-octave bands with centre frequencies lying in the frequency range 200 Hz to 5 000 Hz. The ambient noise level in the test space shall be at least 10 dB below the equivalent input noise level as calculated in (e);
- b) Adjust the gain control of the hearing aid to the reference test gain position as described in 6.14.1, using the third-octave band filter centred at 1 600 Hz;
- c) With the sound source switched off, measure the sound pressure level of the output noise in the coupler for third-octave

*Octave, half-octave and third-octave band filters for analysis of sound vibrations.

bands with centre frequencies in the range 200 to 5 000 Hz (Example A). To determine that the noise in the coupler and the coupler microphone system is adequately low, the measured noise should decrease by at least 10 dB when the hearing aid is turned off;

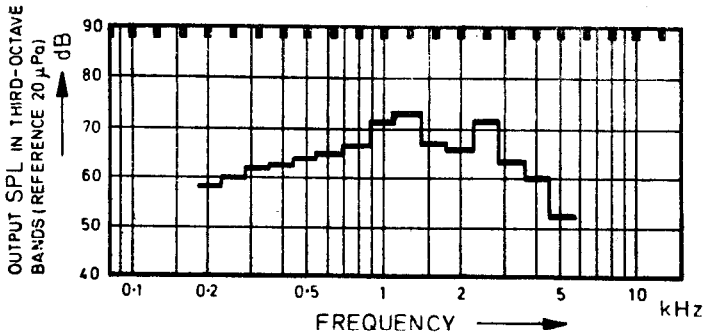
- d) For the same gain control setting, determine the acoustic gain for pure tones as the difference between output and input sound pressure levels at the centre frequencies of the third-octave filters (Example B);

The gain should be determined using a stated input sound pressure level of either 60 dB or a lower level if necessary to ensure essentially linear input-output conditions of the hearing aid. AGC aids in particular may require lower input sound pressure levels.

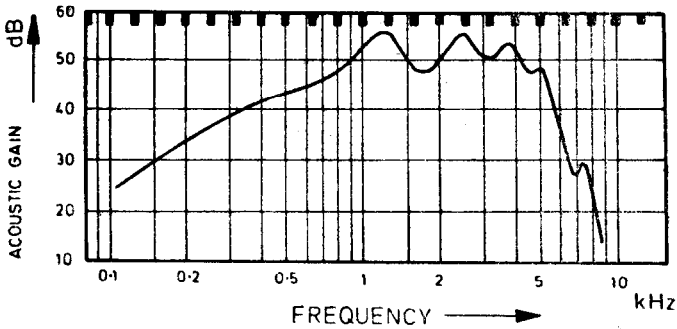
NOTE — Measurements mentioned under (a), (c) and (d) may be carried out by continuous recording.

- e) The equivalent input noise level for each third-octave band is obtained by subtracting the pure-tone gain as measured in (d) from the noise output level as measured in (c) (Example C).

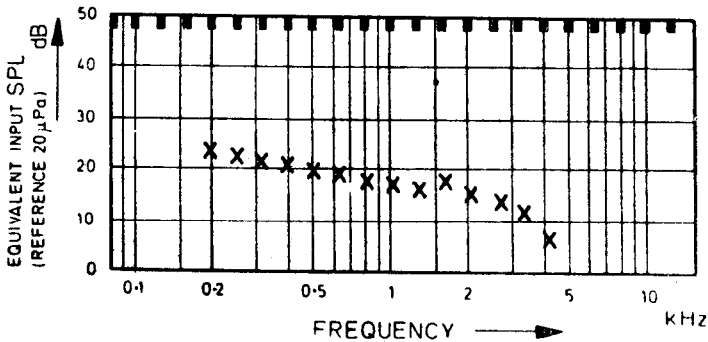
NOTE — Equivalent input noise levels for frequency bands in which the pure-tone gain varies by more than 10 dB per third-octave should be identified as it may be difficult to interpret the results.



1A. Recording of the sound-pressure level of noise output in third-octave bands for the reference test gain position of the gain control



1B. Recording of the acoustic gain for pure tones with an input sound pressure level of 60 dB and the reference test gain position of the gain control



1C. Calculated equivalent input noise sound pressure levels

FIG. 1 EXAMPLES OF THE DETERMINATION OF THE EQUIVALENT INPUT NOISE LEVEL OF A HEARING AID